(54) **System for the spacial referencing of a direction associated with a moving body with respect to a structure.**

(57) The system enables an accurate spatial referencing of a direction associated with a moving body, eg. a helmet aiming sight. It uses two sensors (3A, 3B) of solid matrix (7A, 7B) type made of charge-coupled devices. These sensors are carried by the structure eg. an aircraft cockpit, and are advantageously formed by miniature cameras. The helmet (2) carries light-emitting bands placed parallel to the direction (DR) to be referenced, these bands being made from either a fluorescent or back-reflecting material. In the latter case, a light-emitting source (15) eg. infrared, is used to illuminate them. The referencing is based on the fact that the analysis of the image of the bands on the sensors enables the definition of at least two secant planes (PA, PB, Fig.3, not shown) each passing through any of the image bands and the associated corresponding optical centre and that their straight line of intersection is a line parallel to the direction to be referenced. A less accurate system employing but one sensor (Fig. 4, not shown) is also described.
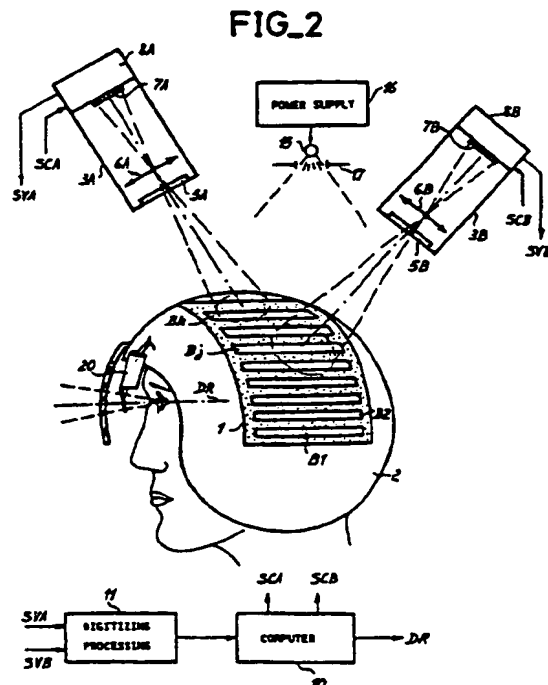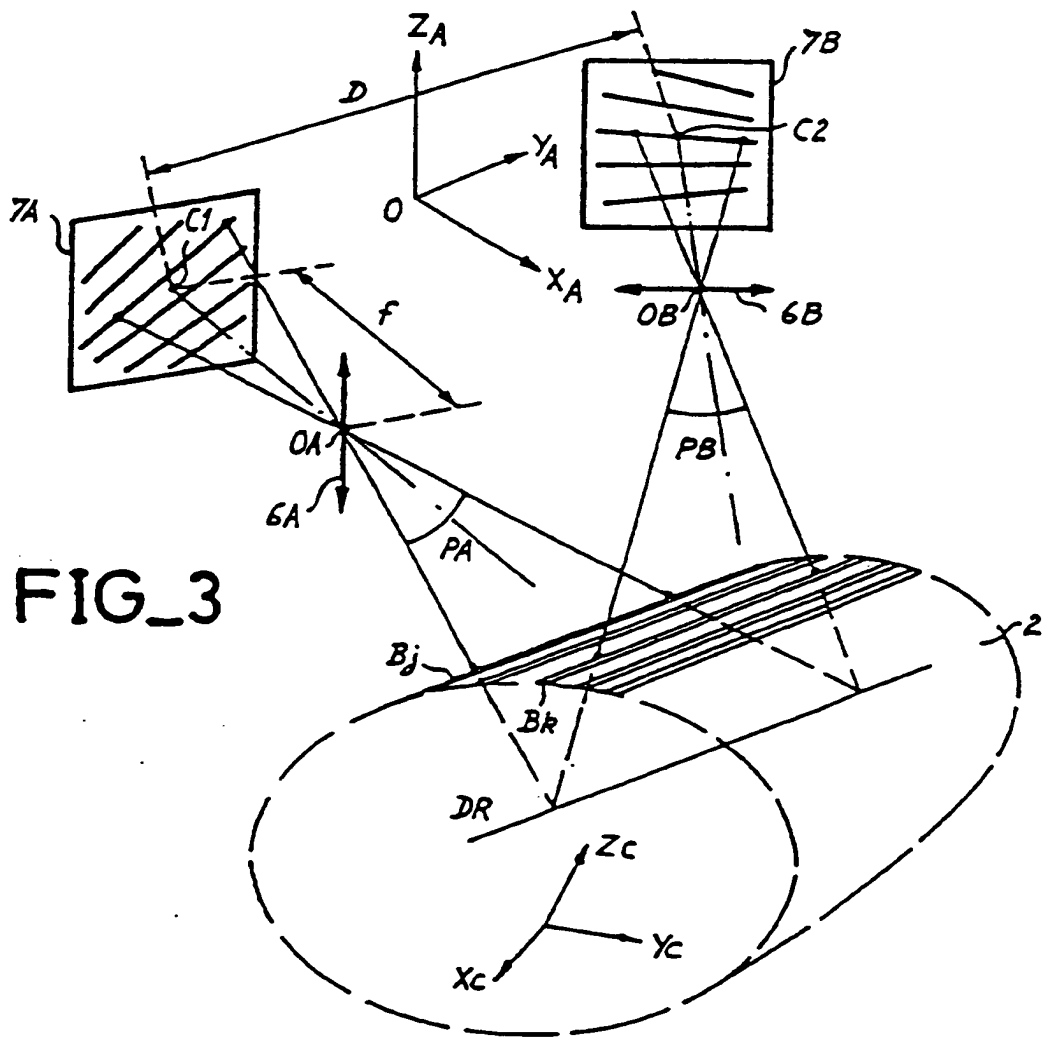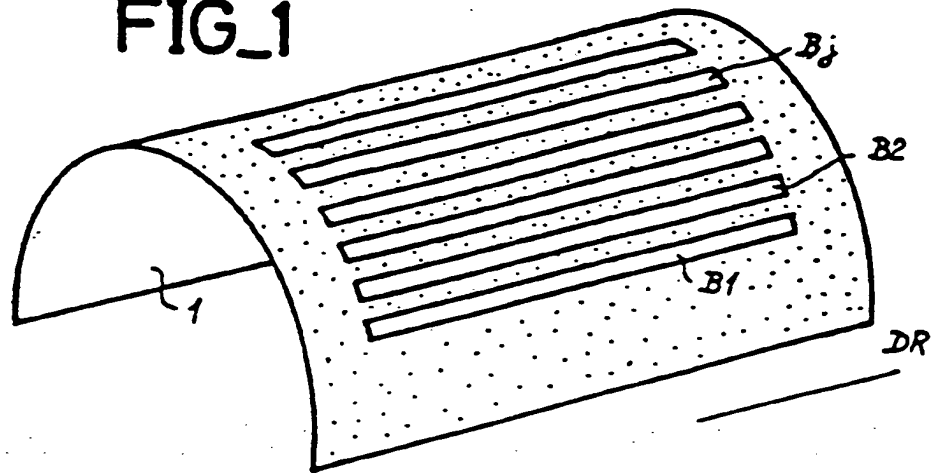
FIG_2

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FIG_1

FIG_3

FIG_2

FIG_4

FIG_5

FIG_6

A SYSTEM FOR THE SPATIAL REFERENCING OF A DIRECTION
ASSOCIATED WITH A MOVING BODY WITH RESPECT TO
A STRUCTURE, USABLE IN PARTICULAR FOR A HELMET
AIMING SIGHT

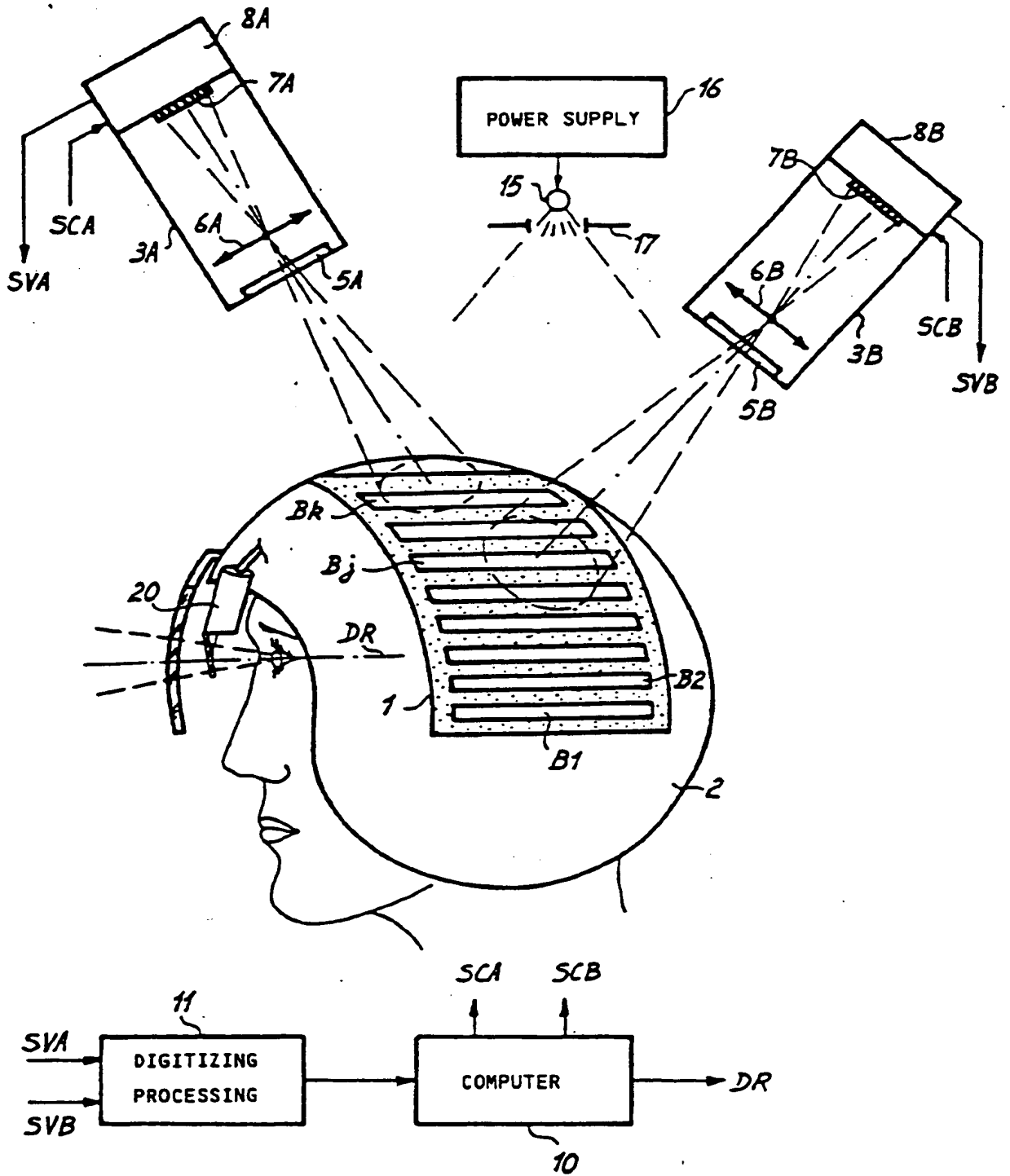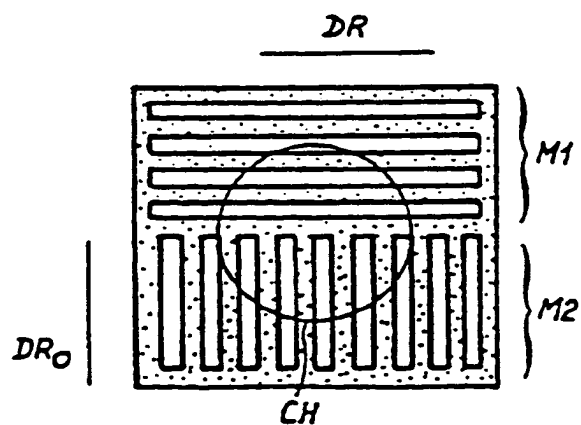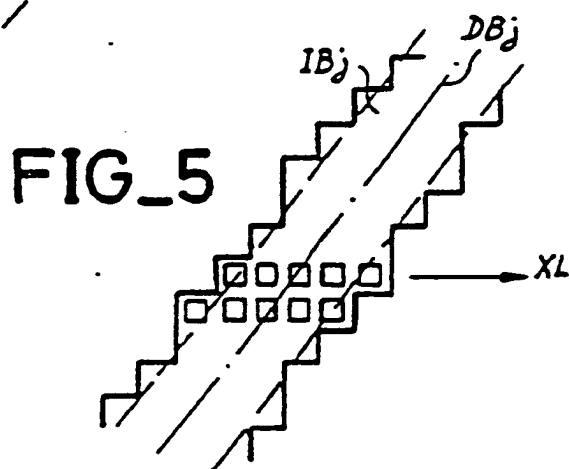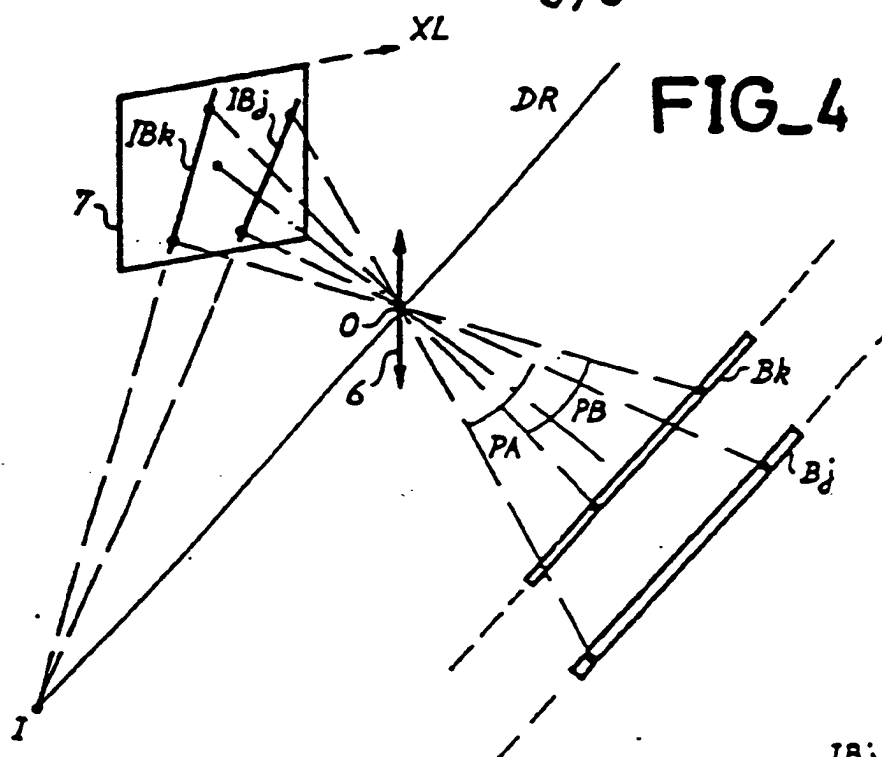The present invention relates to a system for the spatial referencing of a direction associated with a moving body with respect to a structure. Such a system enables the determination of the relative orientation of

5 the moving body with respect to a surrounding structure which is the case in particular for the application more particularly envisaged in the aeronautical field where the moving body is constituted by the pilot's helmet fitted with an aiming sight and the structure is con-

10 stituted by the cockpit.

Systems of this type are produced in various ways which are divided into two major categories, optical solutions and magnetic solutions. The object of the invention relates to an optical type solution. Such a

15 solution can be constituted with a group of light emitting diodes mounted on the helmet, one or more sensors mounted on the cockpit and an appended computer which processes the detected signals in order to measure the reference direction associated with the helmet. A suc-

20 cessive sequential powering of the diodes is produced from the computer. The sensors are mounted in the aircraft and the computer can, at any moment, give the spatial position of a defined direction associated with the helmet, this reference direction preferably being

25 chosen corresponding with the aiming direction of the pilot. A solution of this type is described in particular in the French patent 2,399,033. The sensor is constituted by means of a detector device preferably formed from three sub-assemblies each including a linear

30 array of photo-sensitive elements coupled to a cylindrical diopter of perpendicular direction in order to determine three planes passing through the emitting light source and to produce, by an associated computa-

tion, the corresponding spatial location of that source,
and then that of a triangle formed by a set of three
sources and, consecutively, to determine the direction to
be referenced.

5   A big disadvantage of these devices is in the fact
that the optical efficiency is very poor, given that the
slit associated with the cylindrical diopter is about
150 microns wide and that the light energy transmitted
by the light emitting source through this optical system
10   and this slit and arriving at an element or at several
elements of the detector array remains very limited.

       According to another known solution described in
French patent 2,433,760, the helmet returns a radiation
by back-reflection and this radiation arrives at an X,Y
15   matrix of elements electrically controlled by a control
circuit and by a computing circuit in order to make the
elements pass from the opaque state to the transparent
state according to a predetermined selection program.
A single photo-detector downstream of the matrix powers
20   the computing circuit which provides the angular devia-
tion measurement of the back-reflector device. Several
back-reflectors are provided to perform the function of
diodes and thus to determine a direction associated with
the helmet. According to this solution the electrically
25   controlled matrix can be produced from liquid crystals
of nematic type or by a PLZT ceramics-based optoelectric
shutter device. Such a solution proves to be complex,
its installation delicate and its use requires a certain
period of time in order to scan the matrix element by
30   element.

       The object of the invention is to produce a system
for the spatial referencing of direction which enables
the disadvantages of the abovementioned solutions to be
overcome using solid circuit matrix detector structures.
35   According to the invention it is proposed to pro-
duce a system for the spatial referencing of a direction
associated with a moving body with respect to a struc-
ture, using means of emission carried by the body and

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means of opto-electric detection carried by the structure
in order to define, by analysis of the detected signal
and a computation, secant planes and by the straight
lines of intersection of these planes, the direction to
5 be referenced, **wherein** _____ the detector means
are constituted by at least one solid matrix sensor made
from a charge transfer device associated with focusing
optics, the means of emission being formed by an array
of parallel emitting bands separated by opaque intervals
10 and arranged on the body parallel to the direction to be
referenced, in such a way that the image of the bands on
the detector means is analyzed in order to define at
least two secant planes, each with any image band what-
soever and the **centre** of the corresponding associated
15 optics, and their straight line of intersection which is
parallel to the direction to be referenced.

The features and advantages of the invention will
appear in the following description given by way of
example with reference to the appended figures which
20 show:
- In figure 1, a diagram of the means of emission pro-
duced in the form of fluorescent or back-reflecting
bands;
- In figure 2, a first embodiment of a referencing system
25 **in which the invention is embodied, using two viewing cameras;**
- In figure 3, a diagram illustrating the process imple-
mented in the system according to figure 2;
- In figure 4, a diagram illustrating the process imple-
mented in a system **in which the invention is embodied but** using
30 only a single viewing camera;
- In figure 5, a partial diagram of the image of a band
on a matrix sensor showing the sensitivity presented by
the system for the measurement;
- In figure 6, a diagram of a variant embodiment of the
35 pattern of bands for measuring the roll of the moving
object about the direction to be referenced.

Figure 1 shows a geometric pattern constituted of
bands B1, B2, ... Bj ... etc. ... emitting light,

parallel to a reference direction DR to be referenced.
These bands can be reflecting bands or made from a
fluorescent material or a back-reflecting material. It
is known that these elements are easily produced in the
5 form of an adhesive band or by painting. The separating
intervals between the emitting bands are opaque; they
can be produced by the support part 1 painted with a
matt black paint for example. The support 1 of the
bands can be a plane or a curved surface as shown by way
10 of example by a lateral section of a cylinder. The light
emitting source in the case of fluorescent bands is con-
stituted by the ambient lighting. In the case of back-
reflecting bands, a light source is used whose field of
illumination covers the area of the pattern to be illum-
15 inated; this source is situated in the vicinity of the
optoelectric detector devices.

Figure 2 shows an example of embodiment of the
referencing system applied to a helmet aiming sight, it
being understood that the referencing of directions is
20 not limited to this case. In this example, the means of
emission detailed in figure 1 are carried by the pilot's
helmet 2 which constitutes a moving body with respect to
the surrounding structure which is the cockpit of the
aircraft. The surrounding structure is fitted with two
25 optoelectric sensors 3A, 3B which are of the solid
matrix detector type produced with charge transfer
devices known as CTD devices. In this first version,
two sensors can consist of two standard miniature cameras
3A and 3B, each of the cameras including a means of
30 optical filtering 5, for example an interferential
filter, an optical objective 6 and the detector matrix
7 which is followed by scanning and reading circuits 8.
These circuits can be remote controlled from an associa-
ted computer 10 which produces the corresponding control
35 signals SC. The detected video signals SV (SVA and SVB
respectively) are processed in circuits 11 and transmit-
ted to the computer 10 in digital form in order to carry
out the computations of the direction DR. The cameras

are directed towards the helmet such that the spatial
volume provided by the displacement of the pilot's head
remains within the field of the camera so that this
camera always sees a small section of the geometric
5   pattern constituted by the emitting bands. As the
volume of movement of the pilot's head is limited as is
the optical field covered by the camera, it is possible
to derive from them the dimensions to be produced for
the pattern also taking account of the rather small dis-
10 tance separating this pattern from the detection cameras.
In the case of back-reflecting bands, the device also
includes a source 15, for example a light emitting diode
which emits in the infra-red spectrum. This source is
powered by a circuit 16 and associated with a diaphragm
15 17 in order to illuminate a field enclosing the volume of
movement of the helmet.

     Figure 3 shows the functioning of this arrangement.
The matrices 7A and 7B, as well as the associated
objectives 6A and 6B, are integral with the structure
20 which is referenced by the axes XA, YA, ZA. The bands
B1, B2, etc. ... are carried by the body 2 referenced by
the axes XC, YC, ZC, of the moving body with respect to
the structure. The image of the bands on the sensors
forms an array of straight and generally converging lines
25 (exceptionally, these can be parallel if the optical
axis is perpendicular to the direction DR). If the
image of the bands on each of the sensors is considered,
this band image determines, with the center OA or OB of
the associated optics, a plane which must pass through
30 the corresponding emitting band B_j or B_k. Now, as
these bands are parallel, the intersection of these two
planes PA and PB must be a straight line parallel to the
sought reference direction DR. The position of the
sensors with respect to the reference axes of the struc-
35 ture is known as is the distance D between the centers
C1 and C2 of these sensors. The focal lengths f between
the sensor and the center OA, OB of the associated
objective is also known. Consequently, the computer can

easily determine each of the planes PA and PB with refer-
ence to the XA YA ZA reference axes and from them can
derive the direction of the straight line of intersection
DR, this straight line being able to correspond, as shown
5   in figure 2, with the normal sight aiming direction of
the pilot.

Figure 4 is the functional diagram of a simplified
but less accurate design in which no more than a single
CTD camera is used in order to determine the direction
10   DR to be referenced. On the matrix 7, the image of the
bands forms an array of straight lines converging at a
point I. Any two of the emitting bands is considered,
B_k and B_j, each of which forms, with its image, a plane
passing through the center O of the associated objec-
15   tive. These two planes PA and PB must pass through the
point of intersection I which represents the image of
the points of intersection of the bands B_k and B_j which
is a point projected to infinity. From this it is
derived that the straight line of intersection IO of
20   these planes corresponds with the reference direction
DR to be referenced. The computer 10, as before, deter-
mines the planes PA and PB, as well as the point of
intersection I of the band images (this point is in the
plane of the sensor) and from this it easily derives the
25   straight line of intersection IO representing the direc-
tion DR.

Figure 5 illustrates the accuracy provided by the
described solutions by means of a detailed diagram.
This accuracy is great considering that one band image
30   IB_j can cover several pixels along the direction XL of
line scanning which enables an accurate determination of
the central direction DB_j of the band image IB_j by aver-
aging the detected values.

Thus the proposed system enables the determination
35   of a direction in space with reference to a given set of
reference axes and is particularly applied to the meas-
urement of the orientation of the line of sight of a
pilot with respect to the aircraft axes. It uses one or

two standard cameras, an easy to produce geometric pat-
tern and has numerous advantages, in particular a neglig-
ible weight and volume. In the helmet aiming sight appli-
cation, a graticule collimated by a collimating device 20

5   (figure 2) symbolizes the aiming direction DR which must
be measured. The geometric pattern 1 is placed on the
helmet, either directly if the surface is suitable in
order to obtain a configuration of parallel bands, or
using a support of the type shown in figure 1 if the

10 longitudinal flatness in the direction of the bands is
not sufficiently complied with by the surface of the
helmet.

        The geometric pattern is particularly easy to pro-
duce if the moving body includes a flat surface, or a

15 surface formed by the displacement of a generatrix
parallel with itself, for example a cylindrical surface.
It is then possible to directly stick fluorescent or
back-reflecting bands, parallel to each other, taking
care to make the separating spaces between these bands

20 opaque.

        Among the possible variant embodiments, in order to
take account of the roll of the head, there is used a
first pattern M1 such as described which is oriented
along the reference axis DR and a second pattern M2

25 oriented orthogonally to the first pattern as shown in
figure 6. This configuration can be unique or it can be
of smaller size and repeated several times in the form
of a checker-board on a plane support 1. The referencing
process enables the definition of the orientation DR and

30 of the perpendicular direction DR_0 of the pattern M2.
From this the computer can derive the roll about the
direction DR. The simultaneous measurement of elevation/
azimuth by DR and of head roll by DR_0 makes it essen-
tial that these two patterns remain within the field of

35 the camera, or of each of the cameras. With this require-
ment, the field CH covered by the camera must be larger
than if the roll is not taken into account. The orienta-
tion of the two orthogonal patterns on the helmet can be

any orientation whatsoever. By construction, the aiming
direction in the axes XC YC ZC associated with the moving
body 2 is known and it is known that this direction corre-
sponds with that of one of the patterns and is orthogonal
5   to the direction of the second pattern.

The second version mentioned with one camera is more
economic; it will, however, be noted that the first de-
scribed solution with two cameras is more accurate and
that it can also be used according to the second process
10 (figure 4) for each of the cameras; this allows redund-
ancy in the computation and an even more accurate and
more reliable measurement.

CLAIMS

1. A system for the spatial referencing of a direction associated with a moving body with respect to a structure, using means of emission carried by the body and means of opto-electric detection carried by the structure in order

5 to define, by analysis of the detected signals and a computation, secant planes and by the straight lines of intersection of these planes, the direction to be referenced, wherein _____ the detector means are constituted by at least one solid matrix sensor

10 made from a charge transfer device associated with focusing optics, the means of emission being formed by an array of parallel emitting bands separated by opaque intervals and arranged on the body parallel to the direction to be referenced,

15 in such a way that the image of the bands on the detector means is analyzed in order to define at least two secant planes, each with any image whatsoever and the centre of the corresponding associated optics, and their straight line of intersection which

20 is parallel to the direction to be referenced.

2. A system according to Claim 1, wherein the bands are made from fluorescent material.

3. A system according to Claim 1, wherein the bands are made from back-reflecting material and

25 in that the means of emission also include an emitting source which emits in the direction of the bands.

4. A system according to either of Claims 2 and 3, wherein _____ the bands are stuck on a support whose surface is constituted by the displacement of a

30 generatrix, the bands being parallel with this direction.

5. A system according to Claim 4, wherein the opaque intervals are produced with matt black paint.

6. A system according to any of Claims 1 to 5,

35 including _____ two matrix sensors constituted by CTD matrix cameras.

7.   A system according to Claim 6 when appended to
Claim 3, wherein _____ the cameras are fitted with
means of optical filtering   in a wavelength band
corresponding with the radiation emitted by the emitting
5 source.

8.   A system according to Claim 7, wherein
        the radiation is located in the infra-red range.

9.   A system according to any of the previous Claims,
used for a helmet aiming sight on board an aircraft,
10 wherein _____ the detector means are mounted on
the aircraft structure   and the bands are
placed on the pilot's helmet.

10. A system according to any of Claims 1 to 8,
wherein _____ the bands are placed directly on the
15 moving body   insofar as this moving body has a flat
surface or a surface resulting from the displacement of
a generatrix parallel with itself.

11. A system for the spatial referencing of a direction
associated with a moving body with respect to a structure
substantially as described hereinbefore with reference
to the accompanying drawings and as shown in Figures 1 to
3 and 5 of those drawings or modified substantially as
described with reference to and as shown in Figure 4 and/
or Figure 6 of those drawings.

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CLAIMS

1.   A system   for the spatial referencing of a direction
associated with a moving body with respect to a structure,
using means of emission carried by the body, means of opto-
electric detection carried by the structure ————————

5   ——————————————————————————————— and means
of computation to define, by analysis of the detected
signals and a computation, two secant planes and, by the
straight line of intersection of these two planes, the
direction to be referenced, wherein the detector means are

10   constituted by n, where n is at least equal to one, solid
matrix sensors made from a charge transfer device associated
with focusing optics, and the means of emission are formed
by an array of parallel emitting bands separated by opaque
intervals and arranged on the body parallel to the direc-

15   tion to be referenced, such that images of the bands on the
n sensors maybe analyzed by the computation means to define
at least two secant planes, each defined by an image of one
of the bands and the centre of the corresponding associated
optics, and the straight line of intersection of these two

20   planes, which is parallel to the direction to be referenced.

2.   A system   according to Claim 1, wherein
      the bands are made from fluorescent material.

3.   A system   according to Claim 1, wherein
      the bands are made from back-reflecting material and

25   in that the means of emission also include an emitting
source   which emits in the direction of the bands.

4.   A system   according to either of Claims 2 and 3,
wherein ——————————— the bands are stuck on a support
whose surface is constituted by the displacement of a

30   generatrix, the bands being parallel with this direction.

5.   A system   according to Claim 4, wherein the opaque
intervals are produced with matt black paint.

6.   A system according to any of Claims 1 to 5, wherein n
is equal to two and wherein the two matrix sensors are

35   constituted by CTD matrix cameras.

7.   A system according to Claim 6 when appended to Claim 3, wherein _____ the cameras are fitted with means of optical filtering in a wavelength band corresponding with the radiation emitted by the emitting

5   source.

8.   A system according to Claim 7, wherein the radiation is located in the infra-red range.

9.   A system according to any of the previous Claims, used for a helmet aiming sight on board an aircraft,

10   wherein _____ the detector means are mounted on the aircraft structure and the bands are placed on the pilot's helmet.

10.   A system according to any of Claims 1 to 8, wherein _____ the bands are placed directly on the

15   moving body insofar as this moving body has a flat surface or a surface resulting from the displacement of a generatrix parallel with itself.

11.   A system for the spatial referencing of a direction associated with a moving body with respect to a structure substantially as described hereinbefore with reference to the accompanying drawings and as shown in Figures 1 to 3 and 5 of those drawings or modified substantially as described with reference to and as shown in Figure 4 and/ or Figure 6 of those drawings.

PATENTS ACT 1977
EXAMINER'S REPORT TO THE COMPTROLLER
UNDER SECTION 17(5)
(The Search Report)

13

Application No.

8713983

FIELD OF SEARCH: The search has been conducted through the relevant published UK patent specifications and applications, and applications published under the European Patent Convention and the Patent Co-operation Treaty (and such other documents as may be mentioned below) in the following subject-matter areas:-

UK Classification F3C (CGB, CGD, CGX); G1A (AEE); H4D (DL)

(Collections other than UK, EP & PCT:)   Selected US specifications from IPC sub-classes F41G, GO1B, GO1S

DOCUMENTS IDENTIFIED BY THE EXAMINER (NB In accordance with Section 17(5), the list of documents below may include only those considered by the examiner to be the most relevant of those lying within the field (and extent) of search)

Category	Identity of document and relevant passages	Relevant to claim(s)
	None	

CATEGORY OF CITED DOCUMENTS

X   relevant if taken alone
Y   relevant if combined with another cited document
P   document published on or after the declared priority date but before the filing date of the present application
E   patent document published on or after, but with priority date earlier than, the filing date of the present application

Search examiner K E Williams

Date of search 28 January 1988

SF :